

The perception of biological motion by infants: An event-related potential study

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Abstract

The current study investigates how human infants process and interpret human movement. Neural correlates to the perception of biological motion by 8-month-old infants were assessed. Analysis of event-related potentials (ERPs) resulting from the passive viewing of upright and inverted point-light displays (PLDs) depicting human movement indicated a larger positive amplitude in right parietal regions between 200 and 300 ms for observing upright PLDs when compared with observing inverted PLDs. These results show that infants at 8 months of age process upright and inverted PLDs differently from each other. The implications for our understanding of infant visual perception are discussed.

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The detection and interpretation of biological motion is critical for recognizing conspecifics [4]. Behavioural research suggests that humans detect and interpret biological motion very early on in development as shown by a preference to attend to biological motion when compared with stimuli depicting other forms of motion, such as drifting dots. One issue that is vital to our understanding of ontogenetic processes in the human species is how the identification of conspecifics develops within the first postnatal year.

Much behavioural research has been conducted on infants' perception of biological motions (see [1], for a review), depicted by points of light moving as if attached to the major joints and the head of a moving person [9]. Three- and five-month-old infants discriminate point-light displays (PLDs) from ones in which the temporal patterning of the lights are perturbed, even when the perturbation includes the same inter-relational mathematical vector translations as undisrupted PLDs [4,11].

It has been conjectured that multiple processing constraints, including stored knowledge of the human form, contribute to the interpretation of point-light displays throughout ontogeny [1]. This supposition is supported by findings indicating that

5-month-old infants do not discriminate point-light displays depicting unfamiliar agents, such as a four-legged spider, from a perturbed version [3]. Also, upright PLDs of human movement have been shown to be immediately recognizable, whereas inversion of the PLD disrupts this ability [4,13]. Specifically, the PLD contains rigid alignments between specific connections, consistent with fixed relationships between components of the human body. It was found that 3- to 5-month-old infants discriminated rigid from nonrigid PLDs in an upright but not inverted orientation [4]. However, to date the assessment of neural mechanisms associated with the perception of upright and inverted PLDs by an infant population has never been investigated. The examination of these neural mechanisms is important because it stands to provide information on the ontogeny of early visual development and on the relationship between infant and adult visual perception.

Behavioural studies suggest that recognition of a human figure PLD is reduced, although not eliminated, when a PLD is shown inverted [2]. Additionally, previous infant research indicates a familiarity preference for upright PLDs depicting adult locomotion [4]. We hypothesized that the perception of biological motion would manifest itself in an increase in amplitude at posterior scalp sites between 200 and 300 ms in the upright condition relative to the inverted condition. This hypothesis was derived from event-related potential (ERP) studies investigating

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face processing during infancy, where familiarity with the presented stimuli has been shown to modulate the ERP amplitude in this latency in a manner similar to adult processing manifested on the N170 waveform [7]. Indeed, in infant research, the P220–P290 waveform has been named the ‘infant N170’ due to the many cognitive and perceptual properties that it appears to share with this adult waveform [5]. Critically, the N170 in adults, at a variety of posterior locations, including occipital (O1, O2), temporal (T7, T8) and parietal cortex (P7, P3, P4, P8) has been indicated as playing a strong role in the perception of biological motion, with more activation in the right hemisphere than in the left hemisphere [10,12]. In order to further understand the neural mechanisms related to the perception of PLDs during infancy, the current experiment investigates event-related potentials associated with the task of observing upright and inverted PLDs of human movement.

Twelve infants (six males and six females) were tested, with an average age of 8 months \pm 12 days. All infants were born full term (37–41 weeks) and were in the normal range for birth-weight. Another 10 infants were tested but were excluded from the final sample as a result of fussiness ($n=1$), failing to reach the minimum requirements for adequate averaging of the ERP data ($n=6$), or experimental error ($n=3$). The minimum criteria for inclusion was 10 trials per condition, however, each infant contributed 22–49 (mean of 31.4) trials to their average from a mean of 117 viewed presentations of the stimuli. This experiment was conducted with the understanding and the written consent of each participant’s parent, and the ethical committee of the Humboldt University, Berlin, formally approved the research conducted in this laboratory.

Two videos of a male actor were produced using a digital video camcorder. Individual frames were modified in Photoshop so that joints were depicted as white squares. All other aspects of the image were removed and replaced by a black background. There were 15 points of light in total, comprising the spatial locations for toes (2), ankles (2), knees (2), hips (2) elbows (2), hands (2), shoulders (2) and nose (1). Two sequences featured PLDs in an upright position. One sequence featured kicking, whereas the other depicted walking, translating from right to left. Two further sequences depicted the same stimuli in an inverted orientation translating in the same direction as the upright stimuli.

Infants sat on their mother’s lap in a dimly lit sound-attenuated and electrically shielded cabin, at a viewing distance of 90 cm away from a 70 Hz 17-in. stimulus monitor. The experiment consisted of one block with 200 trials (100 upright, 100 inverted).

The two conditions were presented to the infant in a random order with the constraint that the same condition was not presented three times consecutively and that the number of presentations of each set of stimuli was balanced in every 20 clips presented. Each clip lasted 1 s in total. Each trial was preceded by a small triangular fixation object presented in the middle of the screen for 500 ms. Between the presentation of the stimuli, the screen was blank for a random period of between 800 and 1000 ms. If the infant became fussy or uninterested in the stimuli, the experimenter gave the infant a short break. The session ended when the infant’s attention could no longer be attracted to

the screen. EEG was recorded continuously and the behaviour of the infants was also video-recorded throughout the session.

EEG was recorded continuously with Ag–AgCl electrodes from 19 scalp locations of the 10–20 system, referenced to the vertex (Cz). Data was amplified via a Twente Medical Systems 32-channel REFA amplifier. Horizontal and vertical electrooculogram were recorded bipolarly. Sampling rate was set at 250 Hz. EEG data was re-referenced offline to the linked mastoids.

The EEG recordings were segmented into epochs of waveform that comprised a 100 ms baseline featuring a triangular central fixation object and 1000 ms of upright or inverted biological motion. For the elimination of electrical artifacts caused by eye and body movements, EEG data was rejected off-line whenever the standard deviation within a 200-ms gliding window exceeded 80 μ V at any electrode. Data were also visually edited offline for artefacts.

For statistical analysis a time window was chosen around the amplitude peak of the effect from 200 to 300 ms after stimulus onset. ERPs were evaluated statistically by computing the following regions of interest (ROIs): left posterior (P3, CP5) and right posterior (P4, CP6). Variances of ERPs were analysed by a 2×2 repeated measures ANOVA. Analysed factors were (1) orientation (upright \times inverted) and (2) lateralization (left \times right).

We assessed the ERP difference in upright and inverted conditions by considering the mean amplitude in the two conditions. An ANOVA was performed in parietal regions as previous research with adults has suggested that this location may be related to the processing of biological information [10,12].

The ANOVA indicated that there was an interaction between lateralization and orientation, with amplitude differences between conditions in right parietal regions at the latency 200–300 ms when compared with those in the left hemisphere [$F(1,11)=6.767$, $p=0.025$]. As expected, the amplitude was larger in the right hemisphere for upright PLDs ($M=1.95 \mu$ V,

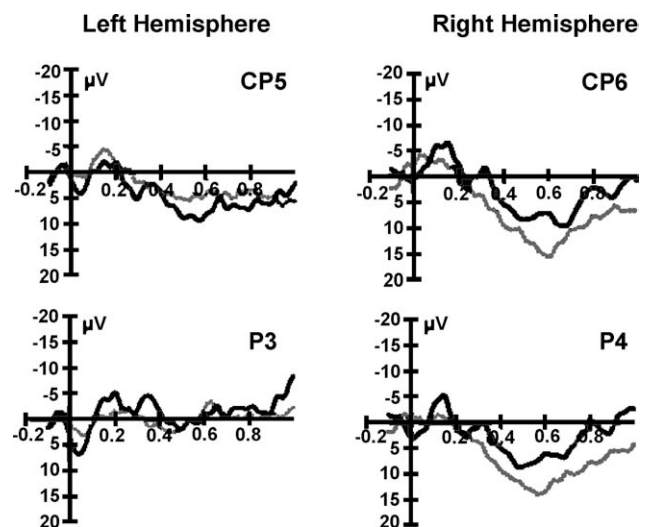


Fig. 1. Left hemisphere (P3, CP5) and right hemisphere (P4, CP6) electrodes, displaying the effect of increased positive amplitude in the right parietal hemisphere for stimuli depicting upright biological motion. Key: grey, upright stimuli; black, inverted stimuli.

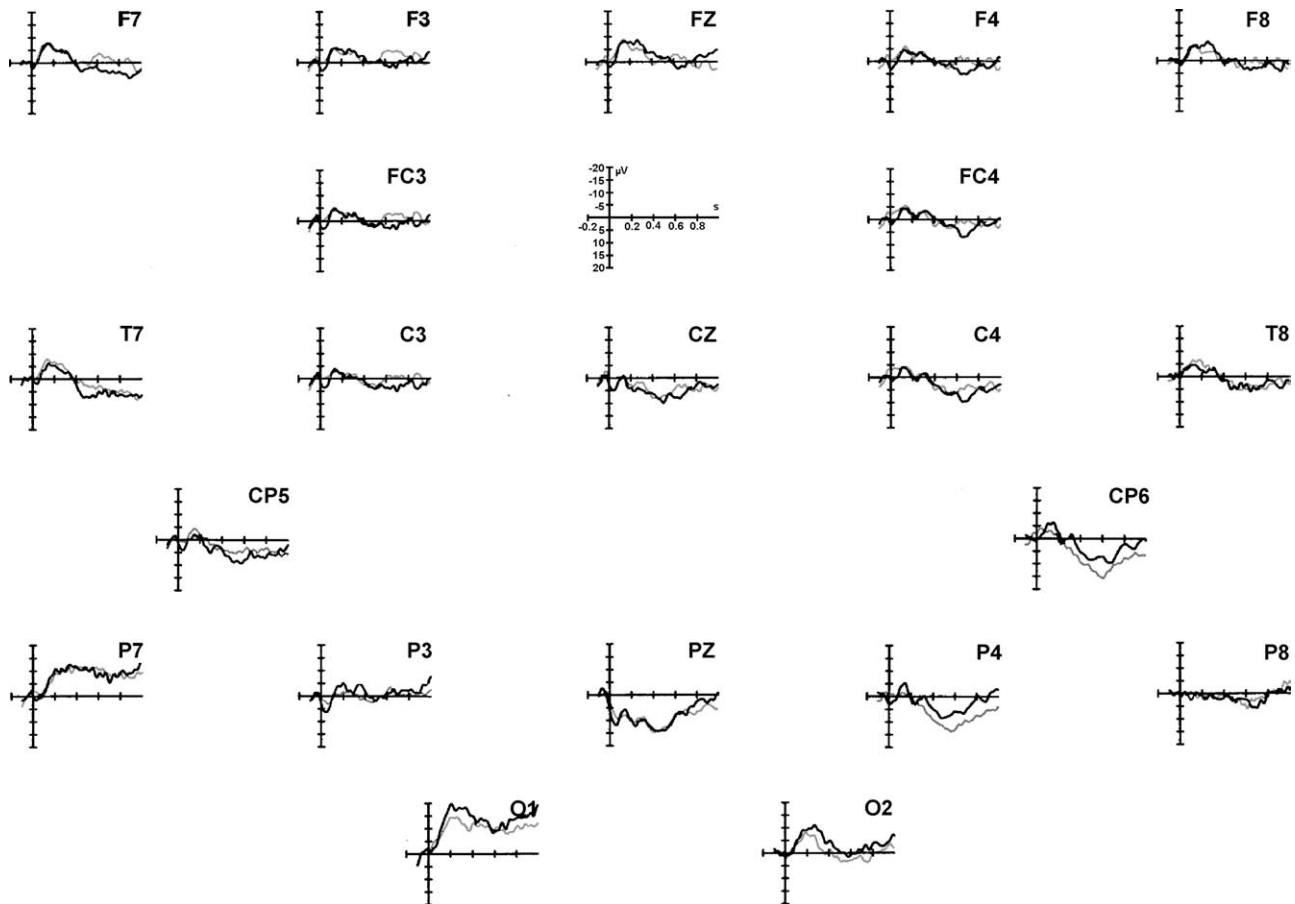


Fig. 2. The Grand Average ERP at all electrode sites ($n = 12$). Key: grey, upright; black, inverted stimuli.

S.E.: 1.23) than for inverted PLDs ($M = 0.34 \mu\text{V}$, S.E.: 1.23) (see Figs. 1 and 2). The grand average and individual averages did not suggest that any other effects were evident at any scalp location (see Fig. 2). No other effects were found.

Here we investigate for the first time the neural mechanisms associated with the perception of upright and inverted PLDs by an infant population. The present experiment is the first neurophysiological data that provides support for the interpretation given to behavioural studies investigating the perception of biological movement with infants. It is now possible to more directly relate infant perception of biological movement to the same task as assessed in adult subjects.

Bertenthal's research [1], demonstrates that infant sensitivity to upright biological motion is related to the perception and detection of biological movement. However, the neural mechanisms associated with the perception of biological movement had never been examined in an infant population. Conversely, much research into face processing by human infants has focused on modulations of the 'infant N170', which in actuality is shown in the waveform to be a P220–P290 [5–8]. Extrapolating from these data, we hypothesized that similar electrophysiological substrates may be involved in the processing of PLD stimuli. Our hypothesis was confirmed with clear effects seen at a similar latency to those detected in infants during face processing.

It is of interest that the effect in this study was lateralized to the right hemisphere. Research into the perception of PLDs

with adults has shown a right hemisphere bias [10,14]. This suggests that even though the morphology of the infant data is ontogenetically unique, the topographical distribution and the latency suggest that these ERPs relate to processes in the human infant brain that are similar at the cognitive level to those seen in the adult brain.

The present experiment suggests that the perception and detection of biological motion begins before 8 months of age. However, in order to state that the neural substrates for processing biological motion begin to mature at 8 months, we would need to test younger infants. Clearly further work is required to understand how the human brain processes biological motion, and how experience influences this ability. The results of the current study provide a firm platform to further assess how biological motion is perceived during early development.

In summary, the results of this study demonstrated that for human infants, right parietal regions are involved in the detection and assessment of biological motion. This finding represents an important first step for the field of infant action perception by determining the neural mechanisms associated with these cognitive tasks.

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